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AN INVESTIGATION OF THE BURROWING INNER-BEACH INSECTS OF SOME FRESH-WATER LAKES *

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EXPOSED sandy beaches of northern lakes often possess three more or less parallel zones which have a certain distinctness, depending somewhat upon local conditions. It is possible to distinguish three zones: (1) inner beach; (2) middle beach; (3) outer beach. The *inner beach* extends from the edge of the water up the slope to the place where the surface sand is no longer saturated with water and where the first traces of drying occur. This zone is relatively narrow and somewhat exposed to the occasional wash of the more gentle waves of calm weather. The *middle beach* occupies the region just shoreward of the inner beach. It is subject to wave contact only during ordinary rough water. In calm weather this zone has a dry surface, although it contains water at deeper levels. The *outer beach* extends from the middle beach to the landward limit of the beach proper. Waves reach it only during violent storms. In the summer it is usually dry to some depth and subject to some shifting of the sand by winds. It may support a few beach plants.

These zones, where produced in typical form, are commonly kept free of the coarser débris, although some of the finer detritus becomes mixed with the sand. During calm weather drifts of organic matter may occur near the water line.

In many inland lakes of the Great Lakes region, and probably elsewhere, the inner beach, when developed, possesses a unique assemblage of burrowing insects which has virtually never been studied. The investigation upon which this paper is based was primarily an ecological one, but attention was also given to life histories and taxonomic relationships.

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Consideration of the burrowing inner-beach insects from an ecological standpoint has heretofore been neglected, and there is almost no literature on the subject. There are but a few brief reports of mud-burrowing forms, such as that of Claycomb (1919), with figures of life-history stages not unlike those of sand-burrowing forms. Klunzinger (1906) and Williams and Hungerford (1911) also described life-history features of certain heterocerids. Andrews (1921) mentioned the occurrence of omophronids, carabids, and heterocerids under débris on beaches. Dury (1902) showed that certain families of Coleoptera include species that burrow, and he contributed a few notes of biological interest. Wickham (1903) also showed that some members of the families dealt with later in this paper are burrowers. No taxonomic references to the larval stages of the species involved in this work are known to the writer.

This work was done at the University of Michigan Biological Station on Douglas Lake, Cheboygan County, Michigan. The shores of Douglas Lake are very suitable for studying the burrowing forms of the inner beach. Also in the vicinity of Douglas Lake there are several lakes whose beaches support such an insect population.

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METHODS

All the species studied make runways or burrows just beneath the surface of the inner-beach sand. Often these burrows attain great length, and at other times are just long enough to cover the hidden insect. Wide sand-bar and sand-spit inner beaches generally support the larger number of burrowers. These beaches are saturated with water, so that tramping lightly on the sand forces the water to the surface and thus destroys the burrows and buoys the insects to the surface. In this manner rapid collecting could

be carried on. Since most of the adult burrowers are good fliers, fast collecting was necessitated if many were to be captured. A slower method of collection was that of digging the insects out of the burrows. A bent dissecting needle or a similar instrument was employed to remove the top of the burrow and expose the animal. At night the writer collected many individuals by using a light to attract them, but this method is unsuccessful for those that do not fly.

For mass collection a soil sieve with a mesh one-sixteenth of an inch was used. A small shovel or a trowel was employed to take up the sand containing insect burrows and to place it in the sieve. The sieve was then carried out into the lake where the water was about twelve inches deep, and by rotating the partly submerged sieve, first in one direction and then in the other, most of the sand was removed. The sieve was then placed in water about three inches deep. Overflow at the rim was avoided, so that the insects were floated on the surface and easily collected.

FAUNA

The insects occurring on the inner beach fall into two categories: (1) those that make their own burrows and live in them most of the time; and (2) those that are not fossorial, but may occupy the burrows made by other species. The former group has been referred to as the true burrowers; the latter, as visitors. These designations indicate more or less the true relation of the insects to the inner beach, as will be shown later. The lists of species given below do not include all the miscellaneous beetles that have been collected from time to time on inner beaches, but give only those which actually belong to this assemblage.

1. TRUE BURROWERS

Dyschirius nigripes Lec.
Dyschirius longulus Lec.
Dyschirius terminatus Lec.
Dyschirius sphaericollis Say
Bembidion confusum Hayw.

Agonoderus pallipes (Fab.)
Homophron americanum (Dej.)
Homophron tessellatum (Say)
Heterocerus auromicans Kies.
Bledius sp.

2. VISITORS

Elaphrus ruscarius Say
Bembidion littorale (Oliv.)
Bembidion transversale Dej.
Bembidion patrule Dej.

Bembidion intermedium Kby.
Bembidion mackinacensis Hatch
Calathus gregarius Dej.
Agonum errans (Say)

Agonum octopunctatus (Fab.)
Chlaenius sp.
Anadaptus discoideus (Dej.)
Hydroporus undatus Say
Chaetarthria sp. Steph.
Stenus stygius Say

Stenus sp.
Gastrolobium bicolor (Grav.)
Philonthus confertus Lec.
Myllaena intermedia Er.
Lucidota nigricans (Say)
Mordellistena cervicalis Lec.

DISTRIBUTION

In the region studied burrowing insects occur with greater frequency on more protected portions of the inner beach. Sand-spits are generally covered with runways of these insects. Sand-bars have many burrows on parts that are rather level and not exposed to wave action. At all times the narrow inner beach accommodates few burrowing beetles but, when present, the burrows are nearer the middle beach. During high waves the zone of burrowing may shift toward the middle beach; quiet surface water may produce the opposite effect.

TRUE BURROWERS

Dyschirius nigripes. — Adults on outer portion of inner beach; mostly in very protected sand-spit regions formed by slowly receding waters; about three inches beneath surface sand; most often in very small tunnels. Eggs, larvae, and pupae not found.

Dyschirius longulus. — Resembles *D. nigripes* in appearance and habitat; differs in its reddish color and wider distribution.

Dyschirius terminatus. — Rare in northern Michigan; collected only on inner side of water-saturated barrier beach bars.

Dyschirius sphaericollis. — Collected on all three types of sandy inner beach; scattered widely on narrow inner beaches, generally on side nearest lake; many on lakeward sides of sand-spits; burrows only fraction of inch beneath surface of sand. Eggs in runways; each egg encased in small sand capsule. First instar larvae producing small tunnels just large enough to permit movement. Larval burrows more numerous on sand-spits; almost imperceptible because of small size and drying of surface sand. Pupae in widened final parts of larval burrows.

Bembidion confusum. — Frequents sand-spits and barrier sand-bars; on those narrow inner beaches in close proximity to other types of habitat. Large burrows infrequent. Individuals active on the surface of the inner-beach sand. Eggs in shallow burrows on

inner beach. Larval runways just large enough to accommodate active movement. Pupae in small cell excavated in burrow.

Agonoderus pallipes. — Rare at times, common at others; adults on the lakeward side of small sand-spits or newly formed sand-bars.

Homophron americanum. — On the older parts of sand-spits and sand-bars; burrows not obvious because of the drying of surface sand; about one inch beneath surface or wherever moisture becomes sufficient to hold sand grains together; found only by recognition of the type of environment. Eggs in burrows; encased in small protective sand capsules. Larval burrows on damper parts of inner beach, producing characteristic runways just beneath surface. Pupae in enlarged part of burrows.

Homophron tessellatum. — Abundant on newly formed sand-spits protected in small coves or harbors; common on narrow inner beaches, but never in large groups. Newly made burrows obvious on all kinds of inner beaches; not permanent. About three inches below surface of sand on old inner beach. Eggs in sand, generally in burrows or just underneath damp sand; enclosed in small protective sand capsules, open at one side. Larval burrows just under surface sand; obvious from above and bizarre in shape. Larvae more numerous than other immature forms on inner beach, or sometimes apparently so, because of their large tunnels; in all types of inner beach; sometimes in rather large aggregations. Pupae in enlarged part of burrows.

Heterocerus auromicans. — Common on wet portions of sand-spits, old barrier sand-bars, and wide inner beaches formed by receding lake waters as flat expanses of very wet sand. Eggs, appearing as very small clusters of whitish balls, in deserted burrows about one inch beneath surface. Larval burrows in the same situation. Pupae in enlarged part of burrows.

VISITORS

On a wide expanse of evenly sloping inner beach partly covered with *Equisetum* one will find *Elaphrus ruscarius*, *Agonum errans*, *A. octopunctatus*, and *Calathus gregarius*. These carabids dart in and out among the vegetation, but seldom enter burrows formed by other species. As the beach narrows and the vegetation disappears one finds very different species. Visitors living on this narrow

inner beach are numerous, but the number of species is small. Among them are *Bembidion transversale*, *B. patrule*, and *B. intermedium*.

Barrier sand-bars support various visiting species, which are especially numerous after the bar has gained connection with the rest of the inner beach. In this group are *Bembidion littorale*, *B. intermedium*, *B. patrule*, *Agonum errans*, *Stenus stygicus*, *Lucidota nigricans*, and *Philonthus confertus*. Sand-spits of all ages have a varied population of visitors, among which are *Bembidion littorale*, *B. patrule*, *B. intermedium*, *B. mackinacensis*, *Agonum errans*, *Hydroporus undatus*, *Stenus stygicus*, *Gastrolobium bicolor*, *Philonthus confertus*, *Myllaena intermedia*, and *Mordellistena cervicalis*. This list does not include all species collected in the inner-beach vicinity.

Quantitative and Qualitative Distribution

Special surveys were made around the inner beaches of Douglas Lake in order to determine the quantitative and qualitative distribution of the burrowing species. One hundred stations were marked around the shores on different types of sandy inner beaches. Uninhabitable parts of the beach were given no consideration. The stations were established one hundred paces apart, chosen at random on the inner beach. A wooden frame, one foot square, was used to mark a certain area on the beach, and all the sand excavated to a depth of six inches was placed in a sieve of appropriate mesh. The burrowing and the visiting insects in this area were collected by this method, as previously described.

Table I gives the actual number of organisms taken on one hundred square feet of sandy inner beach during June and July, 1929-30. It should be noted that the insects were collected from all types of inner beach and at particular stations.

The second survey was made in late August and early September in the summers of 1929 and 1930. The data secured (Table I) show that there had been a decrease in the quantity and the quality of some of the adult forms. The numbers of *B. confusum*, *S. stygicus*, and *H. tessellatum* had increased slightly over those found in the previous survey.

Distribution on Different Lakes

An examination of the inner beaches on other lakes in the Douglas Lake region revealed the presence of burrowing species. Not

all beaches proved equally productive. A few larvae of *H. tessellatum* were secured at various places on the shores of Burt Lake. Other true burrowers were absent. Visitors occurred in large groups, although the variety of species was small; *B. patruale* and *B. intermedium* were the only species collected. However, not all the beach region on this lake was examined. Sand-spit and sand-bar formations on Carp Lake were numerous enough to provide a suitable habitat for burrowing beetles. The true burrowers found were *H. tessellatum*, *H. auromicans*, *B. confusum*, *H. americanum*, and *D. sphaericollis*. *B. littorale*, *B. intermedium*, and *B. patruale* were among the visiting species.

TABLE I

QUANTITATIVE AND QUALITATIVE DISTRIBUTION OF BURROWING
INSECTS ON BEACHES OF DOUGLAS LAKE

All values represent averages.

Species	Number of insects per 100 square feet 1929 and 1930	
	June-July	Aug.-Sept.
<i>H. auromicans</i>	165	85
Carabid larvae.....	31	38
<i>B. confusum</i>	9	14
<i>D. sphaericollis</i>	8	3
<i>B. intermedium</i>	6	3
<i>H. tessellatum</i>	5	5
<i>H. americanum</i>	4	2
<i>B. littorale</i>	4	..
<i>D. longulus</i>	2	1
<i>A. pallipes</i>	2	1
<i>D. nigripes</i>	1	1
<i>D. terminatus</i>	1	..
<i>A. errans</i>	1	1
<i>S. stygius</i>	1	4

Few bog lakes have an exposed shore line sufficiently large to provide a sandy beach. Vincent Lake is an exception, since it has a small amount of beach on one side. Only one burrowing larva was found, the immature form of *B. littorale*. The adults of this species were collected on the same beach, although they do not burrow. No true burrowing adults were found.

The beaches of Munro Lake were prolific in burrowing insects. There were no sand-spits in the early part of the summer, but be-

fore it was half over many had formed. In addition, barrier sand-bars were scattered up and down the shore lines for a quarter of a mile or more. These species always found to be very prevalent were *H. tessellatum*, *H. americanum*, *H. auromicans*, *B. confusum*, and *D. sphaericollis*. Not only were the adults very numerous, but the beaches, because of their stability, provided a very good place for the immature stages of all the species mentioned above. In addition to the true burrowing species, there were numerous visitors, though not representing many species. Visiting species were: *B. intermedium*, *B. patrule*, *A. errans*, *B. littorale*, and *Philonthus confertus*. A few of the rarer burrowers, such as *D. nigripes*, *D. longulus*, and *A. pallipes*, were taken infrequently. The large number of barrier beach bars and sand-spits made Munro Lake as productive as Douglas Lake, although the former had less expanse of inner beach.

PHYSICAL FEATURES OF ENVIRONMENT

WIND ACTION

The influence of wind action on the distribution of burrowing insects, which is largely secondary, is through its effect upon the beaches. It seems to play a primary rôle only when prolonged or extremely high; at such times it forcibly scatters the immature and the adult insects. Wind action may also partly control the food supply, the stability of beaches, and the water content of surface sand.

WAVE ACTION

Burrowers on older sand-spits and barrier sand-bars are not greatly endangered by high waves, but, in instances of freshly formed sand-spits and sand-bars, the highest waves may lash well up the surface. If this portion of the surface is occupied by burrowers, their runways are destroyed and the inhabitants carried on the water. Such species as *H. auromicans* and *B. confusum* are able to fly directly from the surface, but others that are unable to fly swim back to the sandy beach. On reaching the inner beach the insects crawl to a more protected place and make other burrows. Some immature stages are often carried out into the lake and never return; others perform in the same way as the adults in regaining the old habitat.

Wave action on the narrow inner beach is more effective on the

inhabitants than it is on other types of beaches. During excessive wave action the entire inner beach is washed by the waters from the lake, so that if burrowers are present they are washed out. When disturbed, they act as has been previously described, except that they may at times burrow in the middle beach until the waves have abated. Thus wave action causes occupancy of the narrow inner beach to be more hazardous than occupancy of the other two types of habitat.

MOLAR AGENTS

Molar action is here caused by pebbles, stones, and larger sand grains in the beach rubbing together and by the impacts of finer sand grains carried in suspension by the moving water. This effect is produced through the action of winds and waves. The narrow inner beach, because of its situation and formation, has considerable molar action which, when severe, prevents the burrowers from producing runways of any description, and thus makes occupancy almost impossible. Molar agents are not continually active, being virtually absent in times of calm. These statements apply not only to the narrow inner beach, but also to the barrier sand-bars and sand-spits.

WATER CONTENT

The narrow inner beach, because of compactness of the sand due to wave action, does not have an excessive amount of water. When the water content is low, it is difficult for the small burrowing insects to tunnel beneath the surface of the sand; hence they are either absent or occur in limited numbers.

The barrier sand-bars and sand-spits vary in water content according to their age and formation. In the barrier sand-bars of recent development the water content is high, since the surface of the bar is just above the surface of the water and since the sand composing it is not packed. As the bar grows older, more sand is added to its surface, producing a formation that rises higher above the water level. If wave action is present, even in a small degree, the sand is gradually packed. This action continues until the sand-bar possesses a surface that is dry, except for the edges which are in the water. These gradual changes account, in part, for the variations that are noted in the insect population.

Sand-spits always possess high water content. In new sand-

spits the percentage of water is higher than at other times, since their surfaces are just above the water line. As the sand-spit begins to age, the water content becomes reduced in the surface sand. The amount of water in the lower sand layers, however, remains constant. Those insects regularly found in this environment have all the water which they need.

CHEMICAL FEATURES OF ENVIRONMENT

Chemical analyses were made of the water contained in the sand of the inner beach and, as might be expected, it possessed essentially the same chemical features as did the surface lake water. Though some decomposition of the organic matter takes place in the inner beach, the continuity of the contained water with the surface water of the lake and the gentle lapping of the wavelets in calm weather probably keep all accumulations of decomposition products leveled out. Since the chemical features were essentially uniform, the detailed data of the chemical analyses are omitted here.

BIOLOGICAL FEATURES OF THE ENVIRONMENT

VEGETATION

The effect that vegetation plays in the distribution of these insects is slight. Most of the plants consist of small herbs and shrubs, with occasional patches of grass and larger bushes. The narrow inner beach seldom supports plants of any kind, since the physical agents prevent their continued existence. Vegetation acts on the burrowing insects only when it becomes dense enough to hinder or inhibit their activities. On the other hand, vegetation may exert an indirect effect upon those insects dependent upon sand-bars and sand-spits. Barrier sand-bars, when first formed, appear to be rather temporary structures. However, roots of rapidly growing vegetation aid in giving the bar a permanent basis. Also, sand-spits are often kept fixed by vegetation.

FOOD SUPPLY

Plankton washed upon the inner beach sand serves as food for the burrowing insects. In addition to the plankton there are other microorganisms which seem to be regular residents of the inner-beach sand. This latter group is still little known. Also, nothing is yet known concerning the extent to which they serve as food for the

burrowing insects. Therefore, all the discussion in this section deals with the plankton.

The narrow inner beach seldom supports a large amount of plankton material. In certain instances plankton "drifts" cause portions of the inner beach to be heavily infiltrated with plankters. Plankton drifts are usually caused by onshore winds producing onshore waves of a certain velocity. These drifts are temporary, since a slight change either in direction or in velocity of the wind distributes the drifted plankton back into the open lake.

Quantitative counts of microorganisms in the three types of inhabited beaches showed that the narrow inner beach maintained the smallest number; the barrier sand-bars were next in quantity; and the sand-spits maintained the largest number. It was found that the distribution of the burrowing insects depends, to some extent, upon the distribution and the quantity of these food materials.

BURROWS

These insects produce burrows so characteristic that the species making them can be identified by their size and form, but experience is necessary to enable one to recognize the different kinds of burrows since, at first sight, they appear quite similar. The adults of a species may produce one type of burrow, but the larvae of the same species may make an entirely different sort. Larvae of different species have different types of burrows.

Larval burrows vary in size according to the larval instar, but the form of the burrow does not change, no matter which instar produces it. Burrows produced by adults are, at most times, of a constant size and shape peculiar to the species of beetle inhabiting it.

KEY FOR THE IDENTIFICATION OF BURROWS

I. Nonbranching burrows

A. Burrow extending wholly or in part beneath surface stratum of sand

1. No obvious surface connection; burrow at least one inch below surface of sand

a. Simple; horizontal; straight; diameter not exceeding 2 mm.

(Pl. LXV, Fig. 29) *D. nigripes* adults

b. Simple; inclined slightly toward vertical; almost straight; diameter not exceeding 3 mm. (Pl. LXV, Fig. 30)

D. longulus adults

2. Obvious surface connection present; course of burrow inclined more or less downward
 - a. Course of burrow in two portions: (a) upper downward sloping section, followed by (b) horizontal extension (Pl. LXV, Fig. 31) *A. pallipes* adults
 - b. Course of burrow not in two distinct portions
 - (1) Course of burrow inclined
 - (a) Entire course of burrow with slight vertical inclination; depth, 4-5 cm. (Pl. LXV, Figs. 32-33) *H. tessellatum* adults
 - (b) Entire course with great vertical inclination: depth, 1-3 cm. (Pl. LXV, Fig. 34) *B. confusum* adults
 - (2) Course of burrow essentially horizontal; shallow
 - (a) Course irregular; enlargements at intervals (Pl. LXV, Figs. 35-36) *H. americanum* adults
 - (b) Course irregular, but diameter constant (Pl. LXVI, Fig. 37) *B. confusum* larvae
 - B. Burrows in surface layer
 1. Course of burrow irregular; surface perforations in burrow (Pl. LXVI, Fig. 38) *D. sphaericollis* adults
 2. Course of burrow straight; surface perforations absent (Pl. LXVI, Fig. 39) *D. sphaericollis* larvae
- II. Branching burrows; near surface
- A. Burrows with main tunnel
 1. Lateral burrows branching off from main burrow; diameter constant
 - a. Branches rebranching (Pl. LXVI, Fig. 40) .. *H. tessellatum* larvae
 - b. Branches simple (Pl. LXVI, Fig. 41) *H. americanum* larvae
 2. Lateral burrows branching off from main burrow always smaller in diameter (Pl. LXVI, Fig. 42) *H. auromicans* larvae
 - B. Burrows without main tunnel, burrows branching; course extremely tortuous (Pl. LXVI, Fig. 43) *H. auromicans* adults

DESCRIPTIONS OF BURROWS

D. nigripes adult

Burrows about 7.5 cm. under surface; unbranched; slightly vertical course, later turning horizontal. Direction straight; diameter not over 2 mm. Found ordinarily in older portions of sand-bars, sometimes in portions of sand-spits unaffected by seasonal changes. Length, 10-30 cm.

D. longulus adult

Burrows 2.5–7.5 cm. beneath surface; unbranched; entire course inclined slightly from surface to depth of 7.5 cm. Diameter, 2–3 mm., seldom 4 mm. Same locality on beach as those of *D. nigripes*. Length, 10–40 cm.

A. pallipes adult

Surface entrance into burrow. Course simple; unbranched; almost vertical, with obtuse angular bend changing course to horizontal; diameter constant. Vertical portion 2–3 cm. in length; horizontal, 2–15 cm.; diameter uniform, 6–8 mm. Found on wet edges of sand-bars and very wet portions of sand-spits.

H. tessellatum adult

Burrow position varying from surface to depth of 4–5 cm. Entrance on surface; raised, open. Tunnel with slight vertical inclination; position not horizontal; unbranched and simple. Diameter of burrow constant, course straight, no angular bends or curves. Diameter inside, 8–10 mm.; outside, 15–20 mm. Length, 3–20 cm. Rare on narrow inner beach; prevalent on sand-bars and sand-spits.

B. confusum adult

Surface entrance into burrow present; course simple and unbranched. Almost vertical; no horizontal elongation; slight terminal enlargements appear as "pits" in beach sand. Diameter constant with exception of terminal enlargement; 6–10 mm. Depth, 1–3 cm. On surface sand-bars and sand-spits.

H. americanum adult

Burrow depth varying down to 2 cm.; unbranched. Course essentially horizontal; tunnel irregular, with obtuse and acute angular curves. Diameter of burrow irregular, notable enlargements at curves in course; no extension in vertical direction. Diameter varying; 8–10 mm. Length, 3–40 cm. On wet portions of sand-bars and sand-spits, occasionally on narrow inner beach.

B. confusum larva

Varying from surface to 2–3 cm. beneath. Course horizontal, very irregular, angular curves generally obtuse, occasionally acute.

Tunnel unbranched; diameter constant, increasing with later larval instars. Diameter of burrow of first larval instar less than 1 mm.; that of last larval instar as much as 5 mm. Length, 1-40 cm. Pattern constant for various instars. On surface and edge of sand-bars and sand-spits.

D. sphaericollis adult

Surface burrow easily visible. Course irregular, unbranched, twisting from right to left; curves gentle, never abrupt. Surface perforations sometimes present; few. Burrows sometimes uncovered. Diameter of burrow inside, 30 cm. On parts of narrow inner beach, barrier sand-bars, and sand-spits.

D. sphaericollis larva

Surface burrow; unbranching; course straight; few if any irregularities. Inside diameter in first larval instar less than 1 mm. Form of burrow constant for all larval instars, diameter increasing to 4 mm. Length varying with larval instars; 1-30 cm. Mostly on sand-bars and sand-spits.

H. tessellatum larva

Burrow entirely at surface; multiple branching; very complex; course of main tunnel irregular, curved, branches given off laterally; 2-6 branches not unusual. Number of branches not constant; diameter varying with larval instar, constant throughout whole system. Course of branches irregular; length always less than main tunnel. Diameter first larval instar burrow less than 1 mm., increasing with instars to 6 mm. Same pattern always in evidence. Length of main tunnel, 10-70 cm.; of first branches, 10-40 cm.; of second and third branches, 5-20 cm. On all types of inner beach, most common on sand-spits.

H. americanum larva

Surface burrow; easily seen in sand; branching and complex. Position entirely horizontal; course of main tunnel irregular; branches given off laterally, at about right angles to main burrow. Branches not rebranching; never so long as main tunnel; number 2-10; diameter varying with larval instar, but not in one complete system. Diameter in first larval instar less than 1 mm.; in last larval instar, 6 mm. Pattern constant. Length of main tunnel,

5-60 cm.; of branches 1-20 cm. Found on wet sand of bars and spits.

H. auromicans larva

Burrow extended entirely at surface; single; simple branching; course of main tunnel twisted, irregular. Small, short branches given off laterally from main tunnel, at about right angles, diameter less than that of main burrow. Course of branches rather straight, largely following direction taken by main tunnel, length much less than 1-4 mm. Length of main tunnel, 5-20 cm.; of branches, 1-8 cm. Mostly in sand-spits.

H. auromicans adult

Burrow near surface; entrance open; whole structure raised above sand surface; completely horizontal; doubly branching and complex; main tunnel absent. From entrance, tunnel extension straight for a few centimeters, branching in either or both directions; branching following tortuous path, sometimes approaching their own origin; rebranching, producing short burrows, also quite irregular. Diameter constant in all tunnels of the burrow system. Final formation very chaotic, no discernible beginning or end. Diameter inside, 4-6 mm.; outside, 7-10 mm. Length quite variable. On all sorts of beach.

RECORDS, PLASTER CASTS

Permanent records of the form of burrows made by the different species were desirable. It was found that plaster of Paris might be used successfully if care was taken in the manner in which it was applied to the burrows. Molding clay was employed to construct a ring around the area of the burrow about an inch in height. This ring prevented the plaster from spreading over too large an area. After the ring had been made, the plaster was poured into it. The mixture of plaster and water was thick before it was poured on the burrow, so that it hardened very fast. When it had hardened sufficiently, it was carefully taken up. As it was raised the top of the burrow clung to the plaster mold, so that the burrow channel was uncovered. The exposed inhabitant was collected, placed in a vial containing alcohol, and given a serial number corresponding to the one written on the mold.

Molds of the burrows were allowed to dry until they were very hard. They were then covered with a very thin coating of soap solution, and another mixture of plaster was poured on the mold. This treatment kept the second pour of plaster from sticking to the mold, and it was easily removed as it reached a harder consistency. By this method a cast of the burrow was made from the mold that had been previously taken from the beach.

Attempts at photographing the burrows met with little success. The sandy beach does not possess a sufficient amount of contrasting color to produce good photographs.

GENERAL BIOLOGY

FOOD

As mentioned previously, the plankton in the inner-beach sand serves as food materials for the burrowing insects. This was shown through feeding experiments, in which the beetles reared were later dissected and the stomach contents examined. Some of the forms were selective in the type of plankters consumed, as will be described in the section dealing with general habits. Plankton was removed from the lake water by Birge cone nets drawn behind a motorboat and was always used soon after collecting to assure fresh food for the burrowers. If the sand already had a large amount of water, it might become flooded by the addition of the plankton. In such instances the excess was removed by withdrawing the water from the lower layers of the sand by means of a syringe bulb and attachments. In this manner the plankters settled upon and into the surface layer of the sand. Since not all the plankton in the sand was eaten it was necessary to change the sand at regular intervals in order to prevent undue putrefaction.

RESISTANCE TO SUBMERGENCE

Since submergence, due to waves and changes in water level, is a standing possibility, it was of interest to determine the ability of these air-breathing forms to resist immersion in water. Adults of the various burrowing species were continually submerged in water for varying intervals. Small beakers were inverted in larger containers filled with surface lake water. Adult beetles were placed under the smaller containers, so that their activity might be watched.

Cessation of activity was no index of the life of the insect. Careful records were kept on the time the insect was active under water. When activity ceased, it was removed at regular intervals to determine whether or not it was still alive. This was the only procedure that gave satisfactory information as to the time when the beetle died. In addition to the work done on adults, a like amount and kind of work was performed on the larvae of the same species. Results of these experiments are stated in Table II.

Immature forms are better able to withstand submergence than are the adults. The adults are not exposed to as great hazards, however, because they will at all times come to the surface of the water and float, whereas the large larvae seldom come to a floating position.

TABLE II

RESULTS OF EXPERIMENTS ON RESISTANCE TO SUBMERGENCE

Five adults and two larvae of each species were tested.

Species	Adults		Larvae	
	Cessation of activity	Death	Cessation of activity	Death
<i>B. confusum</i>	1-2 min.	56-61 min.	25-28 min.	2.5-2.7 hr.
<i>H. tessellatum</i>	2-3 "	60-80 "	48-50 "	2.2-2.5 "
<i>H. americanum</i>	1-4.5 "	61-72 "	21-24 "	2.0 "
<i>D. sphaericollis</i>	2.8-3.1 "	60-61 "	31-34 "	2.5-2.6 "
<i>H. auromicans</i>	36-39 "	60-61 "	61-64 "	2.6-3.2 "

SEASONAL QUANTITATIVE VARIATIONS

In the spring adults of the burrowing species are not numerous in all localities around Douglas Lake. Narrow inner beaches are often completely barren of such species. Barrier-beach bars have a population that corresponds to the type and location of the bar, that is, those bars which have existed all winter and have never been completely submerged or are too far from the water line have burrowing species; those not corresponding to these requirements are not inhabited. Most sand-spits are inhabited with burrowers of different sorts. This is not true if the spit has been too far removed from the water's edge in the late fall of the previous year. Thus,

adults may be taken almost at will in sand-bar and sand-spit environments during the spring.

By midsummer the water in the lake begins to drop. This leaves exposures of sandy beach in those places where the shoal decline is not steep. These newly formed beaches become slowly inhabited by different kinds of burrowing species. After these beaches have become permanent, they are of a modified sand-spit form. Those adult forms which have migrated to this locality are of the old generation, i.e. those that emerged the previous fall. Drop in water level increases the quantity of usable beach for the burrowing species. As it happens, the eggs are laid from the spring to late summer. At the former time the water line is high, and the inhabited portions of the beach are, as has been indicated, the sand-bars and the sand-spits. The eggs hatch into larvae, which burrow in or near the locality where they develop. Sometimes various outside influences disseminate the eggs, so that burrowing larvae are apt to be found on any beach, but are most prevalent on bars and spits. The larvae pass their entire existence in such a situation and pupate at about the same place. After the pupal stage has been completed, the newly formed adults do not migrate far from the place of their emergence. In many instances final transformation occurs so late in the season that, when adults do emerge, they never come to the surface of the sand, so that migration from that area is not apparent. The emergence of newly formed adults thus increases the quantity in the older sand-bars and sand-spits, even though some specimens from the previous generation have migrated.

In the late fall, when ice coats the surface of the lake, the more recently formed beach is covered with ice sheets, and those burrowers which have lived up to this time on the beach die off. Since a greater number of the newly emerged beetles have remained in the older sand-bars and sand-spits, they survive and extend their burrows deeper into the beach. The water is not generally sufficient in the deeper layers of the sand to permit total freezing and, in addition, the upper layers of the sand are at most times protected by a blanket of snow. In this manner the adults of the various species overwinter. The following spring they are found in the localities in which they have spent the winter.

The variation in the quantity of larvae is obvious from what has been related concerning the life history of the burrowing species.

In the early part of the summer season few if any can be collected. In midsummer a few begin to appear, and later on they become quite numerous.

In the early spring adults of *H. auromicans* comprise the bulk of the population. Almost every sand-bar and sand-spit supports many individuals of this species at that time of the year. As the season progresses, the adults oviposit and gradually die off. Near the end of the summer the only adults that remain of this species are those that have recently emerged and that live in the older sand-bars and sand-spits around the beach. These stay where they emerged until the following spring. The larvae of this species are especially numerous from about the middle or the last of August until pupation, which occurs from the middle of September on until late fall.

The adults of *B. confusum* are slightly more numerous in the fall than in the spring. The reason for the larger number in the fall is explained by the fact that the adults of the older generation do not die off until late in the season. Those individuals that have deposited their eggs continue their burrowing activities all through the summer period on into the fall, so that when the new generation comes on they still exist. The larvae of this species are not produced in such great numbers as those of the species just discussed. They are found in collections taken in the latter part of July until the last part of August. By this time most of them have pupated. Pupae are often taken in collections as late as the first part of September, after which time most of the adults have emerged.

The adults of *B. confusum* are the most active of the burrowing species. In the daytime they occur on the surface of sand-bars and sand-spits, actively feeding or running on the moist sand. A few individuals occupy the burrows throughout part of the day, which makes them less obvious. Their habits undoubtedly aid in causing this species to appear more numerous than some of the others.

Adults of *H. tessellatum* resemble those just discussed in seasonal distribution. The spring and summer is a time of low population. Only those adults which have overwintered are present. The incidence of death during the winter season is higher in this species than in any other, so that the number of adults is not large. The eggs are laid about the middle of the summer season, slightly before those of the other species. The larvae, being the largest of this

burrowing group, are taken more often in collections. Not only are they collected more frequently, but their burrows appear much more commonly on the beach. The larvae pupate earlier than most of the other species on the inner beach and, since their period of pupal life is about the same as that of other species present, the new generation of adults appears early. As in the species just described, adults appear in greatest number late in the summer or early in the fall. It happens that the peak in the number of adults occurs at the time described above, and when no other burrowing species are present in significant numbers.

Adults of this species are constant in their time of maximum appearance, as has been shown during four seasons of study. This maximum number also shows that the life cycle is slightly more than a year in length. Most of the adults live a complete year. They are the largest of the true burrowers.

The adults of *H. americanum* are never so common as those of the species just described, although they may be collected in greater numbers in early spring. Those that have overwintered in the sand-bars and sand-spits comprise the largest groups. The females deposit their eggs near the middle of August. At most times the larvae appear in the early fall; they pupate when the season is farther along.

The life history of *D. sphaericollis* does not differ greatly from that of the species just described. It is noted that the adults are commoner in the spring than are those mentioned above, although they are doubtless more numerous at all times. In the early fall the adults begin to die, so that collections at that time show a marked decrease, which is more obvious than in any other species. The larvae and the pupae were never numerous in collections from any lake.

HABITS

Food

As already mentioned, the plankton materials coming into the inner beach make up the food for the burrowing insects. It is interesting to note that the various species of beetles in this amphibious group have different food habits. As the plankton is made up of zoöplankton and phytoplankton, great diversity in kinds of food may occur. The habits of selection of food will be described for each of the burrowing species.

The larvae and the adults of *H. auromicans* have practically the same food habits. The phytoplankton, which comprises a rather large proportion of the plankton crop in Douglas Lake, is used for food. The water content in the sand-bars and sand-spits is sufficient to maintain both single-celled and colonial algae. On numerous occasions the writer has observed adults of this species feeding on *Gloeotrichia* and, at times, on the simpler blue-green algae, such as *Gloeocapsa* and *Merismopedia*. Dissection of the stomach with its contents has never revealed any sort of zoöplankton; nor has this species been observed feeding on animal life of any description.

B. confusum, in the adult stage, feeds on zoöplankton, or on some of the smaller visiting beetles. Most of the plankton forms serving as food are Rotifera, Copepoda, and Cladocera. A few Copepoda recovered from the stomachs of this species were of the kind also found in the sand of the beach, although never in plankton collections from the lake. This beetle has been observed feeding on its own members, but such cannibalism has been mostly restricted to the rearing cages, where sufficient food of other sorts was not furnished.

The food habits of the larvae of this species are not especially different from those of the adults. If possible, the younger larval instars prey on the smaller plankters. When the plankters are almost as large as the predators, an interesting struggle sometimes ensues, in which the larva is generally victorious.

The adults and the larvae of *H. tessellatum* are probably the least selective of any species of this assemblage. They are quite predaceous. The largest Crustacea and Algae serve as food for the adults. The daily consumption is most astounding when one considers the size of the animal doing the feeding. They get the planktons that are in the sand or they may migrate down to the edge of the water and pick up those that have been washed in. They have been maintained for a long time on Algae, and they have been kept alive on animals for just as long a period without any apparent detriment. As in the species previously described, they are cannibalistic if the necessity arises. Individuals which have recently emerged are much more exposed to capture.

H. americanum, in the adult stage, feeds on the zoöplankton more than do the larvae. The adults, as shown by dissection and observation, do not generally feed on the phytoplankton, although they may in case of want. The larvae, on the other hand, resemble

those of the species just described in being unselective in their diet. Almost any living thing found in the plankton material is eaten. Not infrequently cannibalism is practiced where they are brought in close proximity. The older larval instars do feed on members of their own size, but the tendency is to feed on the younger ones. In like manner the adults prey on other beetles that are on the beach. These are not often members of their own species, but generally they are some of the smaller visiting forms. Cannibalism has been observed but rarely in nature.

D. sphaericollis is the only species of this group that is truly omnivorous. Living plankton, or almost any organic remains, is eaten freely. This species commonly feeds upon the surface débris of the inner beach. Unlike most of the other species, it is not generally found feeding on the materials that are in the sand of its burrow. Its burrows are apparently used only as a housing place, but never so much so as those of the other species. The larvae are not carnivorous; they feed only on plankton materials. This peculiar type of feeding is especially interesting, since it involves a habit unique in this association.

Very closely associated with this group is a staphylinid, *Bledius* sp., which doubtless aids in completing the work that has been started by the other species, i.e. this form is almost entirely a carrion feeder and serves to clean up the sand materials of organic remains.

Breeding

The breeding habits of the various species of this group have been observed numerous times. Some rather distinct peculiarities have been seen which are uncommon to those species that do not burrow and which have doubtless developed along with the burrowing habit. These do not normally occur in all the species, but they will be described briefly for those insects that show them.

B. confusum, at most times, breeds on the open beach, carrying on the mating activities in a manner typical of active carabids. The males may mate with as many as twenty females in a short interval of time. Apparently, they do not often perform the mating activities in the burrows, although such mating has been found a very few times.

H. auromicans differs slightly in its breeding habits from the

species just described. Most of the mating occurs during the night and may take place in the burrow or on the surface of the beach. Individuals of this species are never overly active; most motions are accompanied by a certain amount of awkwardness. The males have not been observed to mate with more than one female, even in a long interval. Since these beetles are prone to carry on most of their general activities at night, breeding is a nocturnal performance. The fossorial prothoracic legs are of use to the male in grasping the female, although there are no other special morphological adaptations. The males possess stridulating ridges along the ventral side of the first abdominal segments, which they use on various occasions. Stridulations are made in flight or while the males are on the surface of the beach.

H. tessellatum and *H. americanum* have about the same sort of breeding habits. These beetles are quite shy, enough so that mating has been observed only a few times. There are no special morphological adaptations for this behavior. The prothoracic legs of the male are used for grasping the female, encircling the prothoracic portions. The mating, so far as observed, always occurs in the burrows that have been made by the adults. It takes place at night or just shortly after sunset. Since the burrows of this species are occupied by a single individual, the male generally migrates to the burrow of the female during the mating season. Shortly after mating the male returns to his old burrow or constructs a new one. This account applies to individuals of both species. It happens that *H. tessellatum* is the shier of the two, and although the individuals of this species are much more prevalent than those of *H. americanum*, few records of mating are at hand.

D. sphaericollis does not resemble many of the other carabids in its breeding habits. It carries on most of its activities at night, usually in the burrows. The prothoracic legs of the male of this species, which are fossorial, prove useful in mating. Since only one individual of this species lives in a single burrow, one of the sexes is required to migrate. Observations show that either the male or the female will go from its own burrow to the burrow of the other.

Egg-laying

All individuals in this group, with the exception of *H. auromicans*, use sand in constructing protective capsules for the eggs. Ovi-

position occurs mainly during the night or just after sunset. It was observed both in rearing chambers and in nature.

H. auromicans deposits several eggs at one time, which remain together. The bottom of the burrow is usually lined with excreta, on which the eggs are placed. After the eggs have become embedded in this mat of excreta, they are apparently safe from destruction. The visiting forms rarely if ever eat the eggs, even though they come into contact with them. The cluster contains from ten to thirty eggs and resembles a bunch of grapes. These eggs are collected very easily because they float on the surface of the water; they are the only eggs of all the burrowing species that do.

The other members of this group differ from the species just described in the manner in which they place their eggs. In every instance there is, surrounding the individual egg, a protective capsule of sand that is formed in a very clever manner. The egg, when it is thrust out by the female, is covered with a layer of mucilage-like material. When this sticky surface touches the sand, a number of grains adhere to it. The female keeps her ovipositor in contact with the surface of the egg as it is thrust out, so that there is no mucilage-like material at that place. They remain in contact until the material on the outer surfaces of the egg has dried and a complete capsule is formed. At this time the ovipositor is drawn in and the egg remains where it was placed, with a complete covering of sand, except for the point of attachment of the ovipositor.

B. confusum exercises no choice in the distribution of its eggs. If the females are on the surface of the sand during the egg-laying time, the eggs are placed there and at random. If, on the other, hand, they are in their simple shallow burrows, the eggs are deposited in the bottom. *H. tessellatum* and *H. americanum* are a little more selective in the manner in which the eggs are placed. The eggs are deposited at the time of maximum activity of the adults, so that it is not to be expected that the egg will always be laid in the burrows. It is very difficult to distinguish between the eggs of these two species. The egg-laying habits seem to be almost identical.

The eggs of *D. sphaericollis* are the smallest of all that have a protective sand capsule around them. Most females are in the burrows during egg-laying time. However, they may place eggs in different sorts of débris or detritus on the edge of the inner beach or

they may oviposit on the surface of the inner beach in proximity to the region of their burrows.

LIFE-HISTORY STAGES

Heterocerus auromicans (Pl. LXIII, Fig. 1)

Egg

Length, with transparent cover, 0.63–0.69 mm. Width, with cover, 0.48–0.53 mm. Egg length, 0.50–0.57 mm.; width, 0.38–0.43 mm. Dimensions varying with development. Eggs in groups of 10–30. Egg covered separately with transparent tough membrane; surface coarsely reticulate; slightly oval to spheroidal; one end slightly pointed; opposite end rounded to oval; micropyle apparent, on pointed end. Color whitish gray, becoming yellow as egg matures.

Larval Instars

Length of each larval instar 5–9 days. (Measurements of length and head capsule made on preserved materials.) First instar: width of head capsule, 0.32–0.34 mm.; length, 1.1–1.5 mm. Second instar: width of head capsule, 0.41–0.45 mm.; length, 2.0–2.5 mm. Third instar: width of head capsule, 0.53–0.58 mm.; length, 3.9–4.6 mm. Fourth instar: width of head capsule, 0.66–0.74 mm.; length, 6.0–7.0 mm.

Morphological characteristics similar for all larval instars, with the exception of head capsule and length. The description of the fifth instar will serve for any of the larval instars.

Fifth Instar (Pl. LXIII, Fig. 1)

Length of body, 10–12.2 mm.; average, 10.8 mm. Width of head capsule, 1–1.5; average, 1.3 mm. Width of prothorax, 1.4–1.8 mm.; average, 1.6 mm. Length of head and thorax slightly more than one third of entire body length. Shape of head, flattened, convex dorsally; thorax compressed, ventral surface flattened, raised dorsally; abdomen distinctly rounded, subcylindrical, becoming more nearly cylindrical and tapering posteriorly from thorax. Color of body light brown to yellow; head darker, becoming lighter posteriorly.

Head subrectangular; clypeus small; labrum projecting as reg-

ular rectangular plate; mandibles simple, not dentate; maxillae simple, cardo small; palpus almost invisible; labium enlarged, covering large portion between genae; mentum small; antennae very small; scape very small; flagellum composed of three small segments. Ocelli dorsal and lateral, five in number; one ventral, lateral to labium. Dorsal surface of head dark to light brown; Y-shaped epicranial suture; no median suture. Ventral side of head dark anteriorly and laterally; median portion light.

Prothorax subquadrate; angles absent; dorsal plates subtruncate both anteriorly and posteriorly; lateral portions rounded. Entire margins pubescent, sparse in anterior region, dense in posterior. Lateral parts with coarser pubescence; primary setae present in anterior part, three apparent; one prominent in posterior, more removed from edge. Median suture present, connecting with Y-shaped epicranial suture anteriorad, recognized by its light coloration. Anterior two thirds dark, including complete margins; posterior one third light; suture inverted-pyramidal, very faint, median and dorsal.

Mesothorax subquadrate; posterior lateral margins forming obtuse angles. Distinct intersegmental line, sometimes appearing double. Dorsal plates slightly rounded in anterior part, truncate in posterior; lateral margin rounded, not extending to margin of body; sclerites well removed from intersegmental lines in both anterior and posterior. Entire surface of plates pubescent, more apparent near median suture and posterior margin, sparse in lateral parts. Primary setae scattered, anterolateral placement of three in group; four prominent on anterior part of each dorsal plate; three in posterolateral parts of each; two in posteromedian portions; and variable numbers found on margins of body. Mesothorax yellow; pubescence dark; primary setae black. Two dark markings on each dorsal plate; one circular, placed anteromedian; the other oblong, larger, and median.

Metathorax subquadrate; angles absent; sides distinctly rounded. Distinct intersegmental line, posterior one double. Dorsal plates slightly curved at anterior end, less curved posteriorad, curved and rounded latera, closely following contour of body, not extending to margins, removed in both anterior and posterior from intersegmental lines. Pubescence slight, present mostly along median suture, only on plates. Primary setae unevenly scattered; four

on anteromedian portions; four to five anterolateral; four across posterior margin of plate; variable number on lateral margin outside plates; number not always constant; small setae not considered. Color of metathorax yellow; pubescence brown; setae black. Two dark spots on each dorsal plate; one circular, placed anteromedian; the other subquadrate, large, placed median.

Ventral aspect of thorax simple; large portion of each segment occupied by origin of coxae.

Prothoracic coxae wide; procoxacava circular, length and width about equal, shape conical, tapering distad, pubescent. Trochanter small. Femur twice as long as wide, pubescent, diameter about constant, cylindrical. Tibia about three times longer than wide; pubescence at proximal end, tapering toward distal portion; outer portion with three obvious spines; inner portion with three longer and more pointed spines; tarsus subcylindrical, not pubescent, four times longer than wide, tapering distally; one prominent spine on outside; inside, concave, excavated near tip. Leg fossorial.

Meso- and metathoracic legs, similar; pubescence variable; femora more flattened; less fossorial.

Dorsal aspect of nine abdominal segments similar, tapering posteriorly; number and arrangement of dorsal plates variable; first four subrectangular; fifth concavo-convex; sixth rectangular; seventh and eighth subquadrate; ninth flattened anteriorly, rounded posteriorly; tenth not visible; no posterior projections; number and position of primary setae variable; general appearance pubescent; dorsal plates light to dark brown; intersegmental regions light yellow to white; setae black.

Ventral aspect simple; first six segments with chitinized plates, pubescent; last three without plates, pubescent; tenth segment turned under.

Spiracles on mesothorax and first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 26)

Typical exarate pupa. Total length, 5.8–6.4 mm.; average, 6.0 mm. Width including wings (not expanded), 2.8–3.3 mm.; average, 3.0 mm. (Measurements made on preserved materials.) Body color light cream to yellow. Eyes reddish brown, ocelli not apparent. Setae of varying length and size on surface of pronotum and abdomen. Pubescence heavy, distinct, coarse. Head with mouth parts

formed, resembling those of adult; entire head turned under pronotum; not visible from above. Pronotum most apparent structure on dorsal surface. Abdomen with seven segments. Pro- and mesothoracic legs distinctly folded on ventral side of thorax; bend at femorotibial joint. Metathoracic legs straight, projecting beyond metathoracic wing pads. Length of pupal stage 5-10 days.

Bembidion confusum (Pl. LXIII, Fig. 6)

Egg

Length of egg, with sand capsule, 1.76-2.00 mm. Width, with sand capsule, 1.43-1.66 mm. Length, without sand capsule, 0.78-0.82 mm.; width, 0.50-0.52 mm. Dimensions with sand capsule sometimes more variable.

Eggs occurring singly, each covered with sand capsule; capsule opening on one side; number of sand grains variable. Chorion transparent; surface finely pitted, under part reticulate; oblong, elongately oval; one end slightly pointed, opposite end distinctly rounded. Micropyle variable in appearance, on pointed end of egg. Color creamy to dark yellow, changing to buff when mature. Two brownish groups of ocelli showing through chorion immediately before hatching.

Larval Instars

Length of each larval instar 5-9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.40-0.46 mm.; length, 3.2-4.8 mm. Second instar: width of head capsule, 0.54-0.57 mm.; length, 5.2-6.0 mm. Third instar: width of head capsule, 0.65-0.71 mm.; length, 6.4-7.2 mm. Fourth instar: width of head capsule, 0.82-0.90 mm.; length, 8.6-9.8 mm.

Morphological characteristics similar in all larval instars, with exception of head capsule and length. The following description of the fifth instar larva is applicable to all.

Fifth Instar (Pl. LXIV, Fig. 5)

Length of body, 10.9-12.0 mm.; average, 11.3 mm. Width of head capsule, 1.0-1.3 mm.; average, 1.2 mm. Width of prothorax, 1.1-1.4 mm.; average, 1.3 mm. Length of head and thorax slightly more than one third of entire body length. Head subtriangular,

rounded on dorsal, flattened on ventral side. Thorax rounded on dorsal; prothorax equal in length to meso- and metathorax; flattened on ventral. Abdomen subcylindrical, slightly compressed dorsoventrad, tapering posteriorad from fifth abdominal segment. Color light brown to very light yellow; dorsal plates much darker.

Head subtriangular; clypeus small; labrum triangular, not extended; mandibles curved, falcate; retinaculum on inner edge near middle; maxillae large; cardo cylindrical; stipes medium; galea small; palpus cylindrical, four-segmented; prementum with setae; mentum distinct; ligulae and paraglossae apparent; labial palpus with three distinct segments; antennae longer than mandibles; scape distinct; flagellum four-segmented. Ocelli six, lateral, near antennal base. Mandibles lateral and posterior, parts of head dark; rest of head light brown to yellow. Y-shaped epicranial suture. Ventral side of head simple; gula large; entire surface yellow.

Prothorax subrectangular, elongate, subcylindrical, compressed on ventral side; dorsal plates covering slightly over one half of prothoracic surface; truncate on anterior end; anterolateral angles acute; margins slightly rounded; posterior edges rounded; margins of plates removed from those of body. Primary setae small; five across anterior edge of plates; four across posterior border; sparse on lateral edges; variable number on body margins. Median suture connecting with Y-shaped epicranial suture, light-colored. Median portions of plates dark, remainder light.

Mesothorax subquadrate; slightly wider than long; one half as long as prothorax. Intersegmental lines double. Dorsal plates covering most of surface, subtruncate at both anterior and posterior ends, removed from lateral margins; lateral edges of plates slightly rounded. Primary setae small, numerous; line across anterior edge composed of seven on each plate; five in transverse line through median region; four across posterior edge. Sparse pubescence on margin outside plates. Dark markings near median region of each plate, slightly oblong, concavo-convex; remainder of plates light brown; portions outside yellow. Light median suture very apparent.

Metathorax subquadrate, about as wide as long. Distinct intersegmental lines double. One half as long as prothorax. Dorsal plates covering most of surface, slightly curved or rounded, removed from margin of body, posterior edge truncate. Primary setae small, numerous, unevenly scattered; generally five setae on anterior mar-

gin of each plate; three near median portions; eight across posterior edge of each plate; smaller setae variable. Regions outside plates possessing few if any setae or little pubescence. Dark markings covering small area of each plate, about half as long as width of plate, oblong, concavo-convex; remainder of plate dark yellow; region outside plate light yellow. Light median suture very distinct.

Ventral surface of thorax plain; region occupied by coxae.

Prothoracic leg: coxae wide; procoxacava circular, short, conical, tapering distad; trochanter small, not much more than simple ring; femur longer than wide, cylindrical; three sharp, distinct spines on inside; tibia longer than wide, flattened on inside, slightly grooved, distal end dilated; ring of sharp, distinct spines, seven in number; tarsus three-segmented; first slightly longer than wide, flattened on inside; distal ring of spines five in number; second segment conical, tapering distad, flattened on inside; two spines on outside, proximal one large, distal small; third segment, conical claw, tapering on distal end to point.

Meso- and metathoracic legs similar.

Dorsal aspect of eight abdominal segments similar, each wider than long; arrangement of dorsal plates variable, each successive plate from first to eighth segment longer; markings on each plate, first set with two oblong, concavo-convex markings; each of following seven with two oblong and two circular markings. Each segment with lateromedian protuberances; each protuberance with primary setae, varying from three to five. Number of primary setae on plates variable, none on other regions of segments. Color of distinct markings dark; plates light brown, remaining portions light yellow to white. Ninth segment small; two caudal appendages, about twice as long as dorsal portion of segment; appendages slightly curved, cylindrical; three primary setae on outside, one apical. Tenth segment small, developed as pygopod.

Ventral aspect of abdomen plain, pubescent.

Spiracles on laterodorsal portions of first eight abdominal segments, not apparent on thorax.

Pupa (Pl. LXIV, Fig. 28)

Typical exarate pupa. Total length, 5.2-6.0 mm.; average, 5.5 mm. Width including wings (not expanded), 2.6-3.4 mm.; average,

3.0 mm. (Measurements made on preserved materials.) Body color white to light cream. Eyes distinctly reddish brown. Setae sparse, few on thorax and abdomen. Pubescence sparse, fine. Entire mouth parts formed as in adult; head depressed forward, toward ventral side of thorax. Pronotum wide, distinct, largest segment of body. Abdomen with nine segments. Pro- and mesothoracic legs folded on ventral side of thorax; fold at femorotibial joint. Metathoracic legs almost straight, reaching posterior end of abdomen. Length of pupal stage 5–10 days.

Dyschirius sphaericollis (Pl. LXIII, Fig. 10)

Egg

Length of egg, with sand capsule, 1.4–1.6 mm., width, 1.23–1.33 mm. Egg length, 0.75–0.77 mm.; width, 0.46–0.49 mm. Measurements with capsule sometimes more variable. Eggs occur singly, each with sand capsule; opening on side or end; number and size of grains variable, often small to medium. Chorion very transparent; surface smooth; lower layer coarsely reticulate; reticulum areas octagonal to circular. Shape oval and ellipsoidal; one end slightly rounded, opposite partly pointed. Micropyle in center of pointed end, not protruding. Color light cream to white, always lightest of group having sand capsules. Two reddish brown groups of ocelli showing through chorion as egg nears time of hatching.

Larval Instars

Length of larval instars, 5–9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.19–0.22 mm.; length, 1.9–2.6 mm. Second instar: width of head capsule, 0.25–0.30 mm.; length, 2.8–3.2 mm. Third instar: width of head capsule, 0.32–0.36 mm.; length, 3.6–4.0 mm. Fourth instar: width of head capsule, 0.42–0.47 mm.; length, 4.8–5.8 mm.

Morphological characteristics similar in all larval instars with exception of head capsule and length. The description of the fifth instar larva is applicable to all.

Fifth Instar (Pl. LXIII, Fig. 9)

Length of body, 6.7–7.2 mm.; average, 7.0 mm. Width of head capsule, 0.66–0.70 mm.; average, 0.68 mm. Width of prothorax,

0.78–0.80 mm.; average, 0.79 mm. Length of head and thorax about one third of entire body length. Head flattened, slightly convex on dorsal side; thorax rounded; prothorax longest segment; abdomen cylindrical, tapering posteriorad from sixth segment. Color dark, with exception of intersegmental region.

Head subrectangular; clypeus wide, not large; labrum wide, pointed on anterior end, small; mandibles curved, falcate; retinaculum on inner edge near middle; maxillae apparent; cardo not large; stipes, subgulae, palpifer fused; palpus cylindrical, four-segmented; galea small, two-segmented; prementum with setae; mentum slightly elongate, distinct; lingulae obvious; labial palpus with three apparent segments; antennae not quite so long as mandibles; scape round, distinct; flagellum four-segmented. Ocelli six, lateral, color almost uniform, light brown. Y-shaped epicranial suture. Ventral side of head light, plain; gula narrow; genae almost flat.

Prothorax elongate, subcylindrical, slightly wider in posterior portion; entire dorsal surface heavily chitinized; plates covering entire surface area. Primary setae absent; pubescence slight, only on margin, very fine. Median suture connecting with Y-shaped epicranial suture. All parts black, with exception of median suture.

Mesothorax subquadrate, wider than long. Intersegmental line single in anterior, double in posterior. Dorsal plates covering entire surface. Primary setae absent, sparse, fine; pubescence on margins of segment. Entire surface dark, uniform, except median suture.

Metathorax subquadrate, distinctly wider than long. Intersegmental lines double. Dorsal plates covering entire surface except extreme posterior portion. Primary setae absent; pubescence extremely sparse, fine, only on margins. Color dark, with exception of posterior margin of segment and median suture, both lighter.

Prothoracic leg: coxae slightly protruding; procoxacava circular, short; trochanter not so wide as coxa or femur; femur slightly wider than long, conical, tapering at distal end, composed of two lateral parts, equal in width; three primary setae on outer side; tibia about four times longer than wide, composed of two parts, proximal one half as long as distal, cylindrical; two to six primary setae on outer side; tarsus three-segmented, first, cylindrical; about four times longer than wide; primary setae variable, generally two on outside, three on inside; second segment about five times longer

than wide, cylindrical; third segment, conical claw, tapering on distal end to point.

Meso- and metathoracic legs similar.

Dorsal aspect of seven abdominal segments similar; arrangement of dorsal plates similar, each with plates extending completely to anterior portion of segment; edges truncate, slightly short at posterior end; margins of plates rounded, not extending to margin of body; successive segments about same size from first through sixth; seventh slightly smaller; eighth smaller; dorsal plates covering complete surface; ninth segment conical, tapering distal; plates complete; urogomphi small, shorter than tenth segment; tenth segment small, conical, pointed. Pubescence slight, mostly on body margins. Color dark, except in intersegmental region and body margins.

Ventral aspect of abdomen flat; one large oval plate near anterior part of each of first eight segments; five longitudinal plates, two outer, extending length of segment; two lateral, to middle plate, slightly shorter; middle plate shortest, in posterior part. Ventral aspect of ninth and tenth segments plain.

Spiracles visible on laterodorsal portions of first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 25)

Typical exarate pupa. Total length, 5.0–6.4 mm.; average, 6.0. Width including wings (not expanded), 1.8–2.5 mm.; average, 2.2 mm. (Measurements made on preserved materials.) Color of body cream to dull yellow. Eyes a reddish brown color. Setae of varying length and size, sparsely scattered on dorsal surface of thorax and abdomen. Pubescence very fine, slightly visible. Head with mouth parts resembling those of adult, whole structure bending forward. Pronotum large, most apparent structure on dorsal surface. Abdomen with nine segments. Pro- and mesothoracic legs folded on ventral side of thorax; fold at femorotibial joint. Metathoracic legs straight, reaching posterior end of abdomen. Length of pupal stage 5–10 days.

Homophron tessellatum (Pl. LXIII, Fig. 14)

Egg

Length of egg, with sand capsule, 2.06–2.33 mm.; width, 1.73–2.06 mm. Egg length, 1.15–1.19 mm.; width, 0.72–0.75 mm. Di-

mensions with capsule sometimes more variable. Eggs occur singly, each with sand capsule, opening on side. Sand grains variable in number and size, generally coarse. Chorion partly transparent; surface irregular, slightly rough; lower layer densely reticulate; reticulum areas irregular to circular. Shape elliptical, slightly elongate; ends rounded, very similar. Micropyle not apparent. Color tan to dark buff. Two reddish brown groups of ocelli appearing through chorion near hatching time.

Larval Instars

Length of each larval instar 5-9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.26-0.30 mm.; length, 1.0-3.8 mm. Second instar: width of head capsule, 0.39-0.42 mm.; length, 2.5-6.0 mm. Third instar: width of head capsule, 0.60-0.63 mm.; length, 3.7-7.8 mm. Fourth instar: width of head capsule, 0.92-0.95 mm.; length, 5.0-10 mm.

Morphological characteristics similar in all larval instars with exception of head capsule and length. The description of the fifth instar larva may be applied to all. Length of entire body extremely variable. Number and placement of setae slightly variable.

Fifth Instar (Pl. LXIII, Fig. 13)

Length of body, 12.4-13.2 mm., average, 12.8 mm. Width of head capsule, 1.1-1.4 mm., average, 1.2 mm. Width of prothorax, 1.7-2.0 mm.; average, 1.8 mm. Length of head and thorax one third of length of entire body. Head subrectangular, slightly rounded on dorsal. Thorax rounded dorsally; prothorax about equal to meso- and metathorax in length. Abdomen slightly compressed dorsoventrally, tapering from third abdominal segment posteriorly to end. Color light brown to light yellow, dorsal plates darker than other parts.

Head subrectangular; clypeus small, emarginate; labrum small, triangular, pointed on anterior end; mandibles, large, curved, falcate; retinaculum on inner edge near middle, bicuspidate; maxillae rather large; cardo medium; stipes, subgalea, palpifer fused; palpus cylindrical, four-segmented, tapering to point distally; galea two-segmented, tapering to point distally; lacinae apparent; prementum with setae; mentum distinct; ligulae membranous; labial palpus with three distinct segments, tapering distally. Antennae slightly

longer than mandibles; scape round, distinct; flagellum four-segmented; third of same length as both first and second. Ocelli six, lateral. Color, dark band near posterior part of head; remainder light brown to yellow. Y-shaped epicranial suture. Ventral side of head plain.

Prothorax narrow at anterior end, widened at posterior; width about equal to length of segment; dorsal surface with plates complete, except at posterior end; distinctly rounded at anterior end, subtruncate posteriorly, slightly rounded on lateral edges. Primary setae absent on dorsal surface of plates, sparse on lateral portions of segment; pubescence distinct and large on margins. Median suture, connecting with Y-shaped epicranial suture. Distinct transverse marking in median portion, concavo-convex. Anterior edge of segment bordered with longitudinal dark markings; postero-median part dark, remainder light brown to yellow.

Mesothorax subrectangular, wider than long. Intersegmental lines single. Dorsal plates covering about half of segment surface; truncate in anterior portions; angles rounded; posterior margin truncate, distinctly rounded at margin; lateral parts distinctly rounded. Primary setae numerous, of variable size; large setae, two on each plate, extreme anterior end, four across each anterior margin just posterior to edge; four across posterior border; extending slightly on lateral; variable number on body margins; pubescence extensive, very fine, slightly visible. Color, dorsal plates light brown, remainder of body light yellow. Median suture light, distinct.

Metathorax subrectangular, distinctly wider than long. Intersegmental lines single. Dorsal plates extending over most of surface longitudinally, distinctly removed from margins of segment. Anterior margin of plates subtruncate; posterior margins turning in at center; entire margins curved, rounded on lateral. Primary setae numerous, variable; distinct setae, seven across anterior margin of each, one anteromedial in each; two posterolateral; six across each posterior margin. Only very apparent setae counted. Pubescence present on edges of dorsal plates, very fine, especially on body margins. Dark transverse line across dorsal plate, not complete; in anterior portion. Median suture apparent. Color of dorsal plate, except the dark line, a light brown; remainder of segment yellow.

Ventral aspect of thorax simple; large portion of each segment taken up by coxal space.

Prothoracic leg: coxa wide; procoxae oval, wider than long, short; trochanter, equal in diameter to coxa, very short. Femur about as long as width of base, conical, tapering distad; base with long pubescence; five primary setae on outer side. Tibia cylindrical, three times longer than wide, slightly enlarged distally; six large spines on sides, largest on distal part, diminishing proximally. Tarsus three-segmented; first segment as long as width of distal portion; ring of seven spines around distal enlargement; second segment one fourth longer than wide, cylindrical; distal ring of six spines around slightly enlarged portion; third segment much longer than wide, conical, tapering distally; two claws.

Meso- and metathoracic legs similar. Some slight modification and rearrangement of spines.

Dorsal aspect of nine abdominal segments similar; all wider than long except the eighth, which is subquadrate. Arrangement and shape of dorsal plates variable: first subrectangular, second subovate, third subtriangular, fourth subtriangular, fifth subpyramidal, sixth subpyramidal, seventh and eighth subquadrate, and ninth subovate. All plates removed from body margins; transparent layer on outside of body margins. Each segment with mediolateral protuberances; each protuberance with primary setae, four to five. Number of primary setae on dorsal plates variable, none in other regions; absent on plates in eighth and ninth segments. Color of dorsal plates light brown, body color yellow, transparent margin almost clear. Ninth segment small, two caudal appendages (urogomphi) slightly more than twice length of segment proper. Urogomphi cylindrical, slightly tapering distally; primary setae numerous, about fourteen present. Tenth segment developed as pygopod.

Ventral aspect of abdomen plain, except double patches of primary setae on each segment. Setae very small.

Spiracles on dorsolateral portions of first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 23)

Typical exarate pupa. Total length, 5.6–8.4 mm.; average, 7.5 mm. Width including wings (not expanded), 3.2–4.0 mm.; average, 3.6 mm. (Measurements taken from preserved materials.) Color of body white to light cream. Eyes a reddish brown color. Setae absent on dorsal surface of thorax, present on dorsal surface of ab-

domen, two groups on each side of median line. Pubescence not evident. Head with mouth parts resembling those of adult; head turned under prothorax. Pronotum large. Abdomen with nine segments. Pro- and mesothoracic legs folded on ventral side of thorax; fold at femorotibial joint. Metathoracic legs almost straight, sometimes extending beyond posterior end of abdomen. Length of pupal stage 5-10 days.

Homophron americanum

Larval Instars

Length of each larval instar 5-9 days. (Measurements made on preserved materials.) First instar: width of head capsule, 0.22-0.28 mm.; length, 1.0-3.0 mm. Second instar: width of head capsule, 0.37-0.41 mm.; length, 2.0-5.0 mm. Third instar: width of head capsule, 0.52-0.59 mm.; length, 3.0-6.2 mm. Fourth instar: width of head capsule, 0.86-0.90 mm.; length, 5.8-9.2 mm.

Morphological characteristics similar in all larval instars with exception of head capsule and length. The following description of the fifth instar larva may be applied to all. Arrangements of setae differing slightly in various instars.

Fifth Instar (Pl. LXIII, Fig. 17)

Width of head capsule, 1.1-1.3 mm.; length, 7.8-12.5 mm. Other measurements similar to those of *H. tessellatum*.

Head parts similar to those of *H. tessellatum*; color darker; slight difference in arrangement of setae.

Prothorax similar to that of *H. tessellatum*. Setae on surface of dorsal plates. Color different; anterior margin black; remainder dark brown.

Mesothorax similar to that of *H. tessellatum*. Dorsal plates covering more of segment. Primary setae variable, about as numerous. Color darker.

Metathorax similar to that of *H. tessellatum*. Dorsal plates covering more of segment. Primary setae variable, about as numerous. Color darker.

Pro-, meso-, and metathoracic legs similar to those of species mentioned above. Spines variable. General proportions not differing greatly. Color darker.

Abdominal segments similar in arrangement, number, and forma-

tion; about the same as those of *H. tessellatum*. Dorsal plates darker, with dark markings. Primary setae numerous, distinct; arrangement slightly variable. Color of segments, not including dorsal plates, light brown. Mediolateral protuberances, with four to five primary setae. Urogomphi about the same as those in *H. tessellatum*.

Ventral aspect of abdominal segment simple, two rows of primary setae very obvious.

Spiracles present on laterodorsal portion of first eight abdominal segments.

Pupa (Pl. LXIV, Fig. 27)

Typical exarate pupa. Total length, 5.5–7.6 mm.; average, 6.0 mm. Width including the wings (not expanded), 2.8–3.6 mm.; average, 3.2 mm. Other characters not differing greatly from those described for *H. tessellatum*.

Bledius sp.

Last Larval Instar (Pl. LXIII, Fig. 20)

Length of body, 3.7–4.0 mm.; average, 3.9 mm. Width of head capsule, 0.54–0.60 mm.; average, 0.58 mm. Width of prothorax, 0.50–0.52 mm.; average, 0.51 mm. Length of head, with appendages and thorax, almost half as long as entire body. Head flattened, subcordate, attenuated posteriorly; thorax subcylindrical, each segment slightly enlarged in mediolateral portions. Abdomen subcylindrical, tapering from sixth abdominal segment anteriorly to first; last three tapering posteriorly. Color light yellow on body; head and setae darker.

Head subcordate; clypeus small; labrum projecting; mandibles simple, about as long as antennae, straight, apical ends curved; inner surface denticulated, more at distal end of mandibles; maxillae simple; cardo small; stipes fused with palpifer; galea absent; palpus small; labium distinct; mentum small; antennae distinct; scape large; flagellum composed of four segments; ocelli six on each side of head. Pubescence distinct. Y-shaped epicranial suture; light coloration, remainder of head dark.

Prothorax subovate; anterior and posterior angles present; dorsal plates covering most of surface; indentation medioanterior; remainder of anterior margin distinctly curved; lateral margin rounded;

posterior margin subtruncate. Intersegmental lines double posteriorly. Primary setae present, small; two on each plate anteromedian; three at lateral anterior angles; one at posterior lateral angle. Pubescence scarcely present, fine and sparse. Median suture just visible. Color, plates dark yellow, remainder light.

Mesothorax subquadrate; angles absent. Intersegmental lines double anteriorly and posteriorly. Dorsal plates present, removed from body margins; indentation medioanterior; remainder of margin curved; lateral sides curved; posterior margin with median indentation; remainder slightly curved. Primary setae very sparse; one large, median in each plate; one small anterolateral in each plate. Line of very small setae across posterior border of plates. Pubescence absent. Median suture slightly apparent. Color light yellow, plates slightly darker.

Metathorax subrectangular; angles absent. Intersegmental lines double. Dorsal plates present, covering less area than in other two segments; anterior indentation medioanterior, remainder of anterior margin slightly curved; lateral margins almost straight; posterior margin with rather deep medioposterior indentation, remainder distinctly curved. Primary setae few, one large in center of each plate; small setae; three on posterior margin of each plate. Pubescence absent. Median suture barely visible. Color yellow, plates darker.

Ventral aspect of thorax simple; coxal cavities lateral.

Prothoracic leg: coxa conical; wider at base than long; trochanter small, ring-shaped; femur twice longer than wide, cylindrical, tapering at each end just slightly, two pairs of primary setae on inside; tibia three times longer than wide, cylindrical, tapering at both ends; six primary setae on inside, none on outside. Tarsus three-jointed; first segment three times longer than wide, slightly tapering distally; five spines arranged near apical end; second segment short, conical; four spines toward distal end. Last segment almost perfect cone, small.

Meso- and metathoracic legs similar; variation in the pubescence; spines about the same.

Dorsal aspect of eight abdominal segments similar; form increasing in width from first to sixth segment; slight tapering in seventh, distinct in the eighth and ninth segments. Form and arrangement of dorsal plates variable, all wider than long; plates arranged symmetrically on segment; median indentation visible in anterior mar-

gins of the first seven segments, in posterior of all eight. Mediolateral protuberances present, each with four primary setae. Ninth segment small; no dorsal plate; urogomphi small, solid. Tenth segment apparently absent. General small, fine pubescence on most parts. Color light, except on median portions of plates, which are yellow. Primary setae on plates variable.

Ventral aspect of all abdominal segments similar, simple; setae and plates absent.

Spiracles on first eight abdominal segments, annular.

Pupa (Pl. LXIV, Fig. 24)

Typical exarate pupa. Total length, 3.4–4.2 mm.; average, 3.8 mm. Width including wings (not extended), 1.2–2.0 mm.; average, 1.6 mm. (Measurements taken from preserved materials.) Color of body white to light cream. Eyes distinctly brownish. Setae on lateral portions of each abdominal segment, varying from 1 to 2; none apparent on dorsal surfaces of body. Pubescence obvious on prothorax, coarse; remainder with a very fine clothing of hair, scarcely discernible. Head and mouth parts resembling those of adult, head bending forward. Abdomen with seven segments. Pro- and mesothoracic legs folded under thorax; fold occurring at femoro-tibial joint; metathoracic legs partly folded. Length of pupal stage 5–10 days.

SUMMARY

1. Certain fresh-water lakes possess an assemblage of sand-burrowing insects on the narrow inner-beach or barrier-beach bars, and on sand-spits.

2. This fauna, comprising (1) true burrowers and (2) visitors, is made up of representatives of the following families of the order Coleoptera: Homophronidae, Carabidae, Heteroceridae, Hydrophilidae, Staphylinidae, Lampyridae, and Mordellidae.

3. Adult burrowing beetles are more numerous in the early part of the summer season; the immature forms appear to be more prevalent in the latter part.

4. Each species produces a characteristic burrow. Larvae and adults of the same species make different burrows.

5. Plankton materials on and in the beach serve as food for these burrowing insects. Those maintained in the laboratory for

as long as ten months fed actively on plankton collected from the surface waters of the lake.

6. The entire life cycle is passed in the burrows. There are five larval instars, each fitted morphologically to inner-beach burrowing. The pupal stage is passed in a widened portion of the burrow.

7. The adults of all burrowing species overwinter in the beach, deposit their eggs the following spring, and die off during the summer.

8. Immature stages of the insects involved are illustrated and described in detail for the first time.

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LITERATURE CITED

(The complete bibliography employed in this work is on file in the office of the Graduate School, University of Michigan.)

- ANDREWS, A. W. 1923. The Coleoptera of the Shiras Expedition to Whitefish Point, Chippewa County, Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 1 (1921): 293-390.
- CLAYCOMB, G. B. 1919. Popular and Practical Entomology: Notes on the Habits of Heterocerous Beetles. Can. Entomol., 51: 25, 1 pl.
- DURY, CHARLES. 1902. A Revised List of the Coleoptera Observed near Cincinnati, Ohio, with Notes on Localities. Bibliographical References and Descriptions of Six New Species. Journ. Cin. Soc. Nat. Hist., 20: 1-196, 6 figs.
- KLUNZINGER, C. B. 1906. Über einen Schlummkafer (*Heterocerus*) u. seine Entwicklung in einem Puppengehäuse. Verh. Deutsch. Zool. Gesell., 16: 218-222, 1 fig.
- WICKHAM, H. F. 1903. The Beetles of an Oregon Beach. Ottawa Nat., 17: 49-52.
- WILLIAMS, F. X., AND HUNGERFORD, H. B. 1911. Notes on Coleoptera from Western Kansas. Ent. News, 25: 1-9.

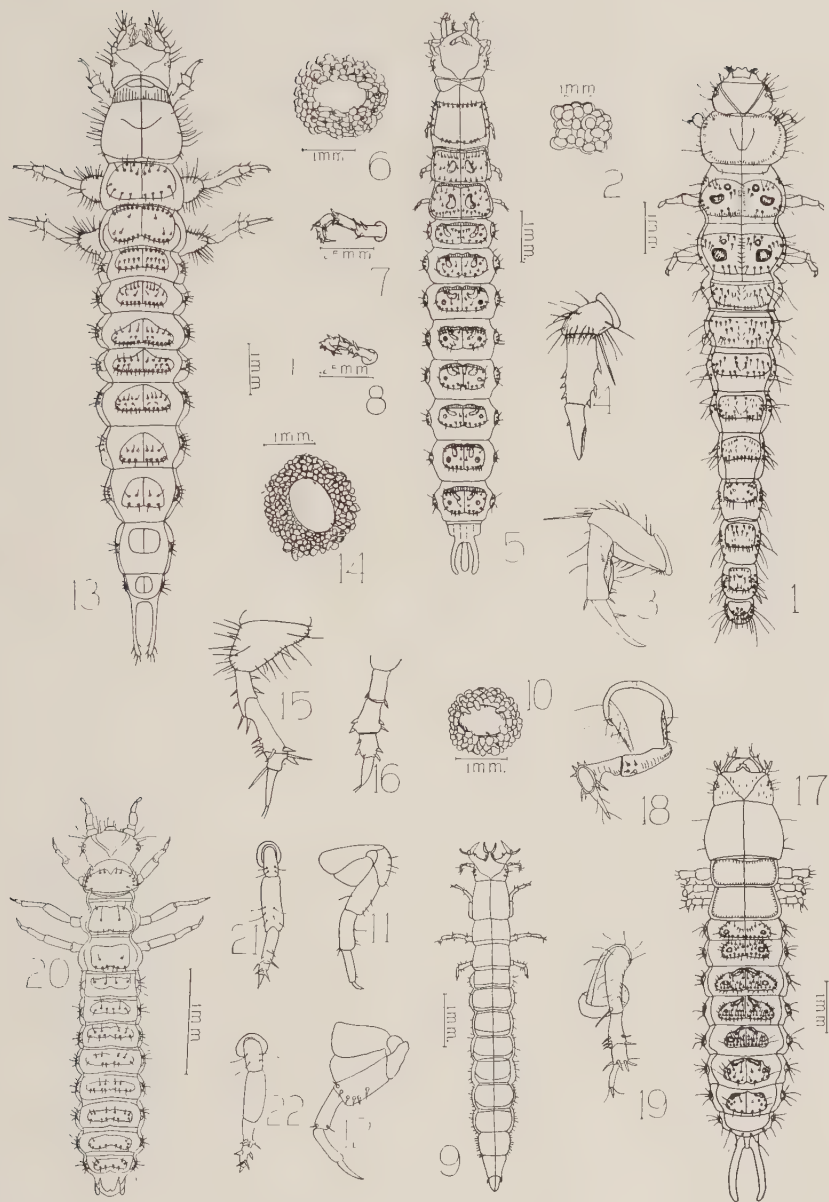
EXPLANATION OF PLATE LXIII

FIG.

1. Fifth larval instar of *Heterocerus auromicans*
2. Group of eggs of *H. auromicans*
3. Larval prothoracic leg of *H. auromicans*
4. Larval metathoracic leg of *H. auromicans*
5. Fifth larval instar of *Bembidion confusum*
6. Egg of *B. confusum*, with sand capsule
7. Larval prothoracic leg of *B. confusum*
8. Larval metathoracic leg of *B. confusum*
9. Fifth larval instar of *Dyschirius sphaericollis*
10. Egg of *D. sphaericollis*, with sand capsule
11. Larval prothoracic leg of *D. sphaericollis*
12. Larval metathoracic leg of *D. sphaericollis*
13. Fifth larval instar of *Homophron tessellatum*
14. Egg of *H. tessellatum*, with sand capsule
15. Larval prothoracic leg of *H. tessellatum*
16. Larval metathoracic leg of *H. tessellatum*
17. Fifth larval instar of *Homophron americanum*
18. Larval prothoracic leg of *H. americanum*
19. Larval metathoracic leg of *H. americanum*
20. Larva of *Bledius sp.*
21. Larval prothoracic leg of *Bledius sp.*
22. Larval metathoracic leg of *Bledius sp.*

NOTE — Additional drawings, which could not be published here, are on file in the office of the Graduate School, University of Michigan.

PLATE LXIII

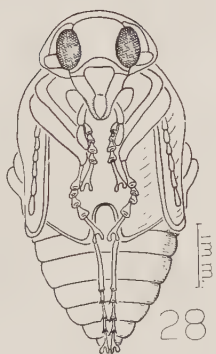
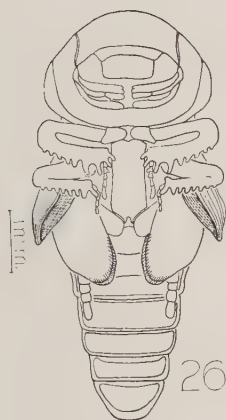
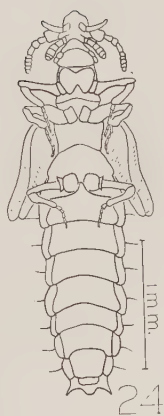
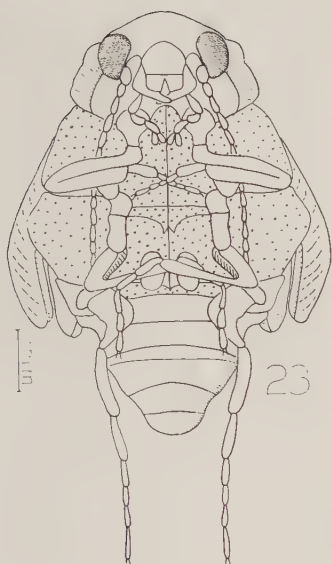


EXPLANATION OF PLATE LXIV

FIG.

23. Pupa of *Homophron tessellatum*, ventral view
24. Pupa of *Bledius sp.*, ventral view
25. Pupa of *Dyschirius sphaericollis*, ventral view
26. Pupa of *Heterocerus auromicans*, ventral view
27. Pupa of *Homophron americanum*, ventral view
28. Pupa of *Bembidion confusum*, ventral view

PLATE LXIV



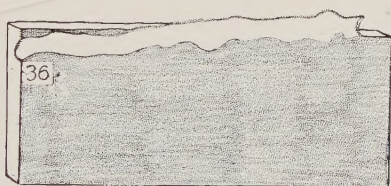
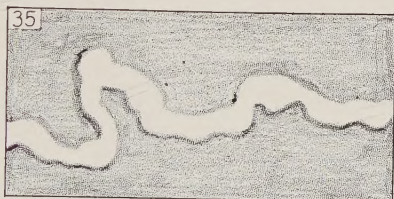
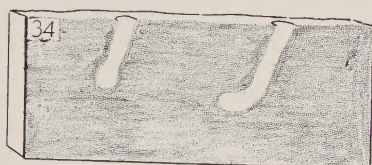
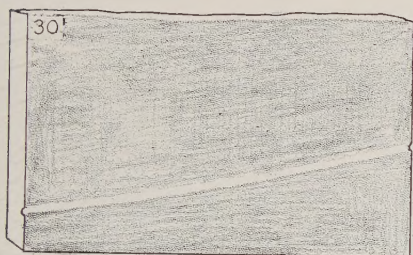
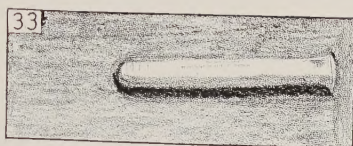
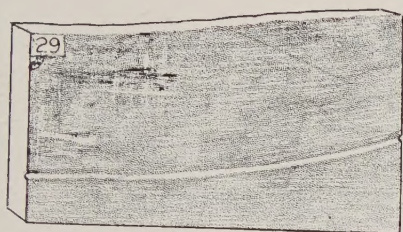
EXPLANATION OF PLATE LXV

Diagrams of insect burrows in sand

FIG.

29. *Dyschirius nigripes* adult
30. *Dyschirius longulus* adult
31. *Agonoderus pallipes* adult
32. *Homophron tessellatum* adult; vertical section through burrow
33. *Homophron tessellatum* adult; surface view
34. *Bembidion confusum* adult
35. *Homophron americanum* adult; surface view
36. *Homophron americanum* adult; vertical section

PLATE LXV



EXPLANATION OF PLATE LXVI

Diagrams of insect burrows in sand; surface views

FIG.

37. *Bembidion confusum* larva

38. *Dyschirius sphaericollis* adult

39. *Dyschirius sphaericollis* larva

43. *Heterocerus auromicans* adult

FIG.

40. *Homophron tessellatum* larva

41. *Homophron americanum* larva

42. *Heterocerus auromicans* larva

PLATE LXVI

